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Citation: Surface Science Spectra **24**, 024001 (2017); doi: 10.1116/1.4998018
View online: http://dx.doi.org/10.1116/1.4998018
View Table of Contents: http://avs.scitation.org/toc/sss/24/2
Published by the American Vacuum Society

# Vanadium, niobium and tantalum by XPS

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(Received 16 March 2017; accepted 20 June 2017; published 22 August 2017)

We present high-resolution XPS spectra of elemental vanadium, niobium and tantalum sputter-cleaned by $Ar^+$ ions. The energy scales are shown without applying any corrections, and the position of the Fermi level was verified to be at zero binding energy within better than 0.1 eV, as determined from the Fermi edge measurement. © *2017 American Vacuum Society*.
[http://dx.doi.org/10.1116/1.4998018]

***Keywords:*** *XPS; vanadium; niobium; tantalum*

**Accession #s:** 01408, 01409, 01410
**Technique:** XPS
**Host Material:** #01408: vanadium; #01409: niobium; #01410: tantalum
**Instrument:** Kratos Analytical Axis Nova
**Major Elements in Spectra:** V, Nb, Ta
**Minor Elements in Spectra:** Ar, O
**Published Spectra:** 23
**Spectra in Electronic Record:** 28
**Spectral Category:** reference

## INTRODUCTION

Combinatorial science deals with complex materials with compositions containing many elements, often with overlapping features in their XPS spectra. At the Joint Center for Artificial Photosynthesis, we explore such material spaces in high-throughput, to find the most suitable catalysts and light absorbers for direct conversion of sunlight into fuels. In order to develop the tools for reliable determination of surface chemical compositions by XPS, we have acquired consistent and comparable reference spectra in high-resolution for all measurable core levels of a particular pure element, or their stable compounds. The data are acquired on the same machine, with the same pass energy and x-ray power; and they contain all measurable loss features. In this publication, we present the results for group five elements.

## SPECIMEN DESCRIPTION (ACCESSION #01408, 1 OF 3)

**Host Material:** vanadium

**CAS Registry #:** 7440-62-2

**Host Material Characteristics:** homogeneous; solid; unknown crystallinity; conductor; metal

**Chemical Name:** V

**Source:** Sigma-Aldrich, Co.

**Host Composition:** vanadium 99.7%

**Form:** foil

**Lot #:** MKBP7987V

**Structure:** bcc

**History & Significance:** 99.7% pure vanadium

**As Received Condition:** as received from supplier (polished)

**Analyzed Region:** not specified

***Ex Situ* Preparation/Mounting:** The foil was cleaned by wiping with isopropyl alcohol, and then mounted under the conductive contact of the sample platen.

***In Situ* Preparation:** Surface was ion-sputtered until no O 1s or C 1s were visible in a high pass energy, wide scan.

**Pre-Analysis Beam Exposure:** no exposure prior to data acquisition

**Charge Control:** no charge control applied

**Temp. During Analysis:** 300 K

**Pressure During Analysis:** $<5 \times 10^{-7}$ Pa

## SPECIMEN DESCRIPTION (ACCESSION #01409, 2 OF 3)

**Host Material:** niobium

**CAS Registry #:** 7440-03-1

**Host Material Characteristics:** unknown homogeneity; solid; unknown crystallinity; conductor; metal

**Chemical Name:** Nb

**Source:** Alfa Aesar

**Host Composition:** Nb 99.95% (metals basis excluding Ta)

**Form:** not specified

**Lot #:** C03Q25

**As Received Condition:** as received from supplier

**Analyzed Region:** not specified

***Ex Situ* Preparation/Mounting:** Mounted on conductive tape on the sample platen in electrical contact with the analyzer.

***In Situ* Preparation:** Surface was ion-sputtered until no O 1s or C 1s were visible in a high pass energy, wide scan.

**Pre-Analysis Beam Exposure:**

**Charge Control:** none

**Temp. During Analysis:** 300 K

**Pressure During Analysis:** $<5 \times 10^{-7}$ Pa

## SPECIMEN DESCRIPTION (ACCESSION #01410, 3 OF 3)

**Host Material:** tantalum

**CAS Registry #:** 7440-25-7

**Host Material Characteristics:** homogeneous; solid; unknown crystallinity; conductor; metal

**Chemical Name:** Ta

**Source:** Sigma-Aldrich, Co.

**Host Composition:** tantalum 99.9% trace metal basis

[a)]Author to whom correspondence should be addressed.

**Form:** foil, thickness 0.25 mm

**Lot #:** MKBW6466V

**As Received Condition:** as received from supplier (polished)

**Analyzed Region:** not specified

***Ex Situ* Preparation/Mounting:** sample was wiped with isopropanol

***In Situ* Preparation:** Surface was ion-sputtered until no O 1s or C 1s were visible in a high pass energy, wide scan.

**Pre-Analysis Beam Exposure:**

**Charge Control:** none

**Temp. During Analysis:** 300 K

**Pressure During Analysis:** $<5 \times 10^{-7}$ Pa

## *INSTRUMENT DESCRIPTION*

**Manufacturer and Model:** Kratos Analytical Axis Nova

**Analyzer Type:** Other

**Number of Detector Elements:** 127

**Analyzer Description:** Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

## *INSTRUMENT PARAMETERS COMMON TO ALL SPECTRA*

### ■ *Spectrometer*

**Analyzer Mode:** constant pass energy

**Throughput ($T=E^N$):** N=See comment below

**Throughput Comment:** The energy dependence is recorded in a file at the time of data acquisition.

**Excitation Source Window:** Aluminum K-alpha monochromatic excitation at 1486.6 eV

**Excitation Source:** Al $K_\alpha$, monochromatic

**Source Energy:** 1486.6 eV

**Source Strength:** 150 W

**Signal Mode:**

### ■ *Geometry*

**Incident Angle:** not specified

**Source to Analyzer Angle:** not specified

**Emission Angle:** not specified

**Specimen Azimuthal Angle:** 0°

**Acceptance Angle from Analyzer Axis:** 35.5°

### ■ *Ion Gun*

**Manufacturer and Model:** Kratos Analytical Ltd. Minibeam IV

**Energy:** 4000 eV

**Current:** 0.120 mA/cm$^2$

**Current Measurement Method:** biased stage

**Sputtering Species:** $Ar^+$

**Spot Size (unrastered):** 500 $\mu$m

**Raster Size:** 2000 $\mu$m × 2000 $\mu$m

**Azimuthal Angle:** 0°

**Comment:** no rotation

## *DATA ANALYSIS METHOD*

**Energy Scale Correction:** No energy shifting has been applied to any spectra.

**Recommended Energy Scale Shift:** We do not recommend any energy scale shifts.

**Peak Shape and Background Method:**

**Quantitation Method:**

## *ACKNOWLEDGMENTS*

This material is based upon work performed by the Joint Center for Artificial Photosynthesis, a DOE Energy Innova:on Hub, supported through the Office of Science of the U.S. Department of Energy under Award Number DE-SC0004993.

| SPECTRAL FEATURES TABLE | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Spectrum ID #** | **Element/ Transition** | **Peak Energy (eV)** | **Peak Width FWHM (eV)** | **Peak Area (eV × cts/s)** | **Sensitivity Factor** | **Concentration (at. %)** | **Peak Assignment** |
| 01408-02 | V $2p_{3/2}$ | 506.60 | 0.60 | 24570 | 1.41 | ··· | V |
| 01408-02 | V $2p_{1/2}$ | 514.15 | 0.63 | 11990 | 0.71 | ··· | V |
| 01408-02 | O 1s | 525.49 | 1.91 | 1970 | 0.78 | ··· | O |
| 01408-03 | V 3p | 31.43 | 0.917 | 3910 | 0.274 | ··· | V |
| 01408-04 | V 3s | 60.30 | 1.99 | 2150 | 0.131 | ··· | V |
| 01408-05 | V 2s | 620.58 | 6.11 | 8540 | 0.673 | ··· | V |
| 01409-02 | Nb $3d_{5/2}$ | 202.26 | 0.433 | 28130 | 1.75 | ··· | Nb |
| 01409-02 | Nb $3d_{3/2}$ | 204.99 | 0.433 | 14070 | 1.17 | ··· | Nb |
| 01409-04 | Nb $3p_{3/2}$ | 360.35 | 2.181 | 38020 | 1.75 | ··· | Nb |
| 01409-04 | Nb $3p_{1/2}$ | 374.86 | 2.181 | 15410 | 0.88 | ··· | Nb |
| 01409-05 | Nb 4s | 56.00 | 4.7 | 1874 | 0.126 | ··· | Nb |
| 01409-05 | Nb $4p_{3/2}$ | 30.60 | 1.13 | 3907 | 0.254 | ··· | Nb |
| 01409-05 | Nb $4p_{1/2}$ | 32.45 | 1.16 | 1954 | 0.127 | ··· | Nb |
| 01409-06 | Nb 3s | 466.55 | 6.76 | 6250 | 0.393 | ··· | Nb |
| 01410-02 | Ta $4f_{7/2}$ | 21.56 | 0.39 | 22000 | 1.761 | ··· | Ta |
| 01410-02 | Ta $4f_{5/2}$ | 23.48 | 0.39 | 16500 | 1.321 | ··· | Ta |
| 01410-02 | Ta $4f_{7/2}$ | 23.06 | 1.06 | 2865 | 1.761 | ··· | Ta-O |
| 01410-02 | Ta $4f_{5/2}$ | 24.98 | 1.06 | 2150 | 1.321 | ··· | Ta-O |
| 01410-03 | Ta $4d_{5/2}$ | 226.33 | 5.69 | 46830 | 2.17 | ··· | Ta |
| 01410-03 | Ta $4d_{3/2}$ | 237.49 | 5.70 | 31380 | 1.08 | ··· | Ta |
| 01410-04 | Ta $4p_{3/2}$ | 401.02 | 6.9 | 26110 | 2.170 | ··· | Ta |
| 01410-04 | Ta $4p_{1/2}$ | 462.20 | 6.9 | 13055 | 1.085 | ··· | Ta |
| 01410-04 | Ta $4p_{3/2}$ | 420.82 | 16.16 | 13690 | 2.170 | ··· | Ta-O |
| 01410-04 | Ta $4p_{1/2}$ | 482.00 | 16.16 | 6820 | 1.085 | ··· | Ta-O |
| 01410-04 | O 1s | 530.80 | 1.55 | 1340 | 0.78 | ··· | O |
| 01410-05 | Ta 4s | 563.02 | 8.135 | 5605 | 0.244 | ··· | Ta |
| 01410-06 | Ta 5s | 68.75 | 8.88 | 2840 | 0.227 | ··· | Ta |
| 01410-06 | Ta $5p_{3/2}$ | 32.51 | 1.60 | ··· | 0.262 | ··· | Ta |
| 01410-06 | Ta $5p_{1/2}$ | 43.71 | 7.51 | 10700 | 0.131 | ··· | Ta |

**ANALYZER CALIBRATION TABLE**

| Spectrum ID # | Element/ Transition | Peak Energy (eV) | Peak Width FWHM (eV) | Peak Area (eV × cts/s) | Sensitivity Factor | Concentration (at. %) | Peak Assignment |
|---|---|---|---|---|---|---|---|
| 1408-07[a] | V Fermi edge | 0 | ··· | ··· | ··· | ··· | Fermi edge |
| 1409-08[b] | Nb Fermi edge | 0 | ··· | ··· | ··· | ··· | ··· |
| 1410-08[c] | Ta Fermi edge | 0 | ··· | ··· | ··· | ··· | ··· |
| 1411-01[d] | Ag $3d_{5/2}$ | 368.24 | 0.52 | 129360 | ··· | ··· | $3d_{5/2}$ |
| 1411-02[e] | Ag $3d_{5/2}$ | 367.69 | 2.00 | 10393 | ··· | ··· | $3d_{5/2}$ |

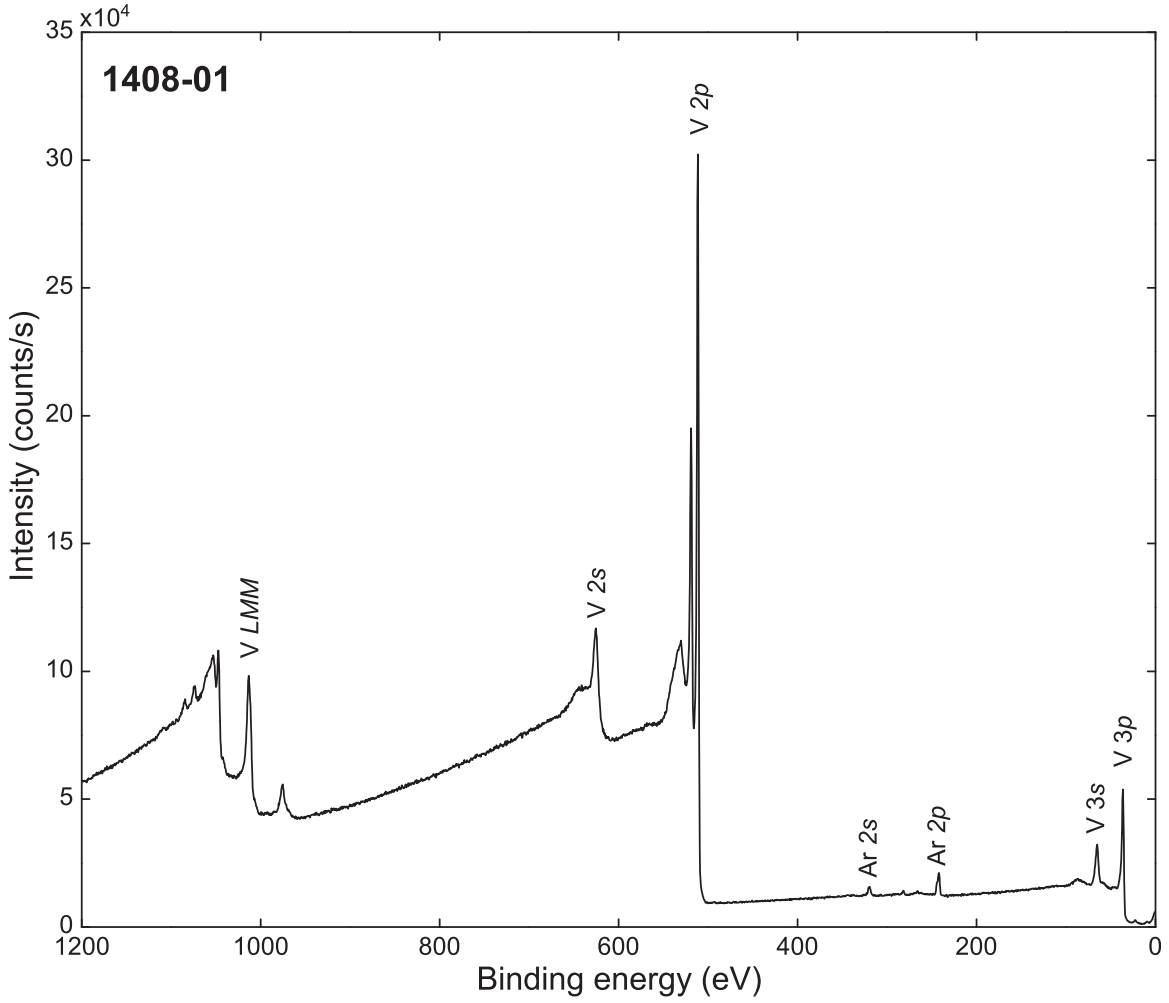
[a] Fermi function fit gives position of the Fermi level at E = 0.056 (0.005) eV, and broadening that includes thermal and instrumental broadening T = 0.094 (0.004) eV, which includes thermal broadening and instrument resolution.
[b] Fermi function fit gives position of the Fermi level at E = 0.073 (0.004) eV, and broadening that includes thermal and instrumental broadening T = 0.093 (0.004) eV, which includes thermal broadening and instrument resolution.
[c] Fermi function fit gives position of the Fermi level at E = 0.023 (0.003) eV, and broadening that includes thermal and instrumental broadening T = 0.094 (0.003) eV, which includes thermal broadening and instrument resolution.
[d] Ag $3d_{5/2}$ calibration peak with passing energy of 10 eV.
[e] Ag $3d_{5/2}$ calibration peak with passing energy of 160 eV.

## GUIDE TO FIGURES

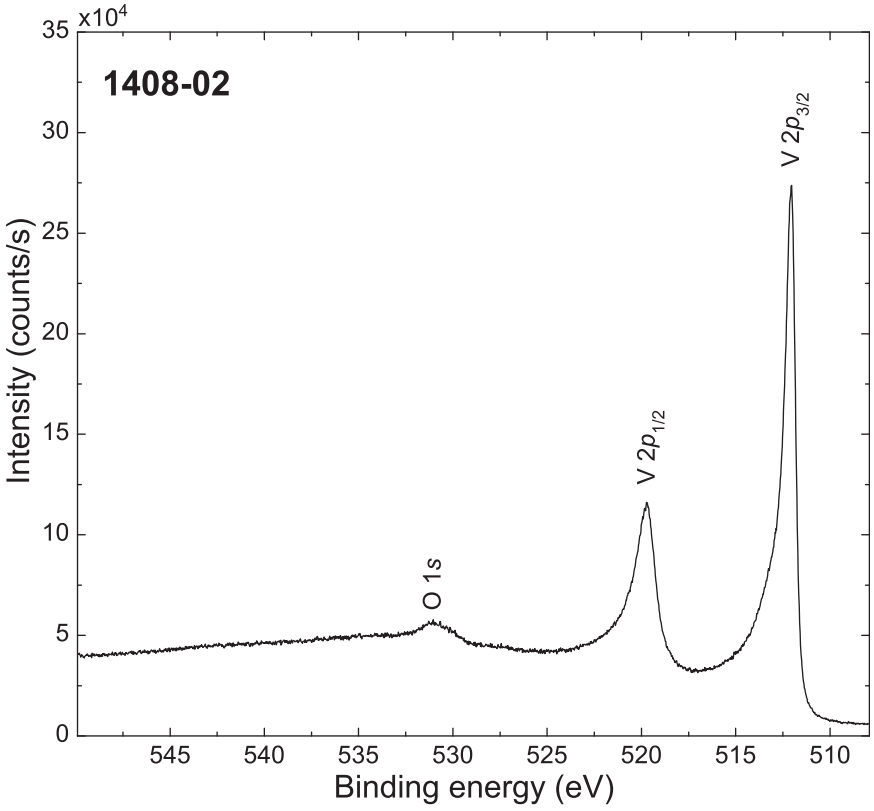
| Spectrum (Accession) # | Spectral Region | Voltage Shift* | Multiplier | Baseline | Comment # |
|---|---|---|---|---|---|
| 1408-01 | survey | 0 | 1 | 0 | 1 |
| 1408-02 | O 1s, V 2p 1/2, V 2p 3/2 | 0 | 1 | 0 | 1 |
| 1408-03 | V 3p | 0 | 1 | 0 | 1 |
| 1408-04 | V 3s | 0 | 1 | 0 | 1 |
| 1408-05 | V 2s | 0 | 1 | 0 | 1 |
| 1408-06 | V LMM | 0 | 1 | 0 | 1 |
| 1408-07 | V valence band | 0 | 1 | 0 | 1 |
| 1408-07 | V valence band, fit | 0 | 1 | 0 | 1 |
| 1409-01 | survey | 0 | 1 | 0 | 2 |
| 1409-02 | Nb $3d_{3/2}$, Nb $3d_{5/2}$ | 0 | 1 | 0 | 2 |
| 1409-03 | Nb $3d_{5/2}$, Nb $3d_{3/2}$ | 0 | 1 | 0 | 2 |
| 1409-04 | Nb $3p_{1/2}$, Nb $3p_{3/2}$ | 0 | 1 | 0 | 2 |
| 1409-05 | Nb 4s, Nb $4p_{1/2}$, Nb $4p_{3/2}$ | 0 | 1 | 0 | 2 |
| 1409-06 | Nb 3s | 0 | 1 | 0 | 2 |
| 1409-07 | Nb MNN | 0 | 1 | 0 | 2 |
| 1409-08 | Nb valence band | 0 | 1 | 0 | 2 |
| 1409-08 | Nb valence band, fit | 0 | 1 | 0 | 2 |
| 1410-01 | survey | 0 | 1 | 0 | 3 |
| 1410-02 | Ta $4f_{5/2}$, Ta $4f_{7/2}$ | 0 | 1 | 0 | 3 |
| 1410-03 | Ta $4d_{3/2}$, Ta $4d_{5/2}$ | 0 | 1 | 0 | 3 |
| 1410-04 | O 1s, Ta $4p_{1/2}$, Ta $4p_{3/2}$ | 0 | 1 | 0 | 3 |
| 1410-05 | Ta 4s | 0 | 1 | 0 | 3 |
| 1410-06 | Ta 5s, Ta $5p_{1/2}$, Ta $5p_{3/2}$ | 0 | 1 | 0 | 3 |
| 1410-07 | Ta NNN | 0 | 1 | 0 | 3 |
| 1410-08 | Ta valence band | 0 | 1 | 0 | 3 |
| 1410-08 | Ta valence band, fit | 0 | 1 | 0 | 3 |
| 1411-01 [NP]** | Ag $3d_{5/2}$, Ag $3d_{3/2}$ | 0 | 1 | 0 | 4 |
| 1411-02 [NP] | Ag $3d_{5/2}$, Ag $3d_{3/2}$ | 0 | 1 | 0 | 4 |

* Voltage shift of the archived (as-measured) spectrum relative to the printed figure. The figure reflects the recommended energy scale correction due to a calibration correction, sample charging, flood gun, or other phenomenon.
** [NP] signifies not published; digital spectra are archived in *SSS* database but not reproduced in the printed journal.

1. Vanadium foil
2. Niobium slug
3. Tantalum foil
4. Ag pellet




| Accession # | 01408–01 |
|---|---|
| **Host Material** | vanadium |
| **Technique** | XPS |
| **Spectral Region** | survey |
| **Instrument** | Kratos Analytical Axis Nova |
| **Excitation Source** | Al $K_\alpha$ monochromatic |
| **Source Energy** | 1486.6 eV |
| **Source Strength** | 150 W |
| **Source Size** | not specified |
| **Analyzer Type** | Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA) |
| **Incident Angle** | not specified° |
| **Emission Angle** | not specified° |
| **Analyzer Pass Energy:** | 160 eV |
| **Analyzer Resolution** | 2.0 eV |
| **Total Signal Accumulation Time** | 3616.5 s |
| **Total Elapsed Time** | not specified |
| **Number of Scans** | 3 |




- **Accession #:** 01408–02
- **Host Material:** vanadium
- **Technique:** XPS
- **Spectral Region:** O 1*s*; V 2$p_{1/2}$; V 2$p_{3/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

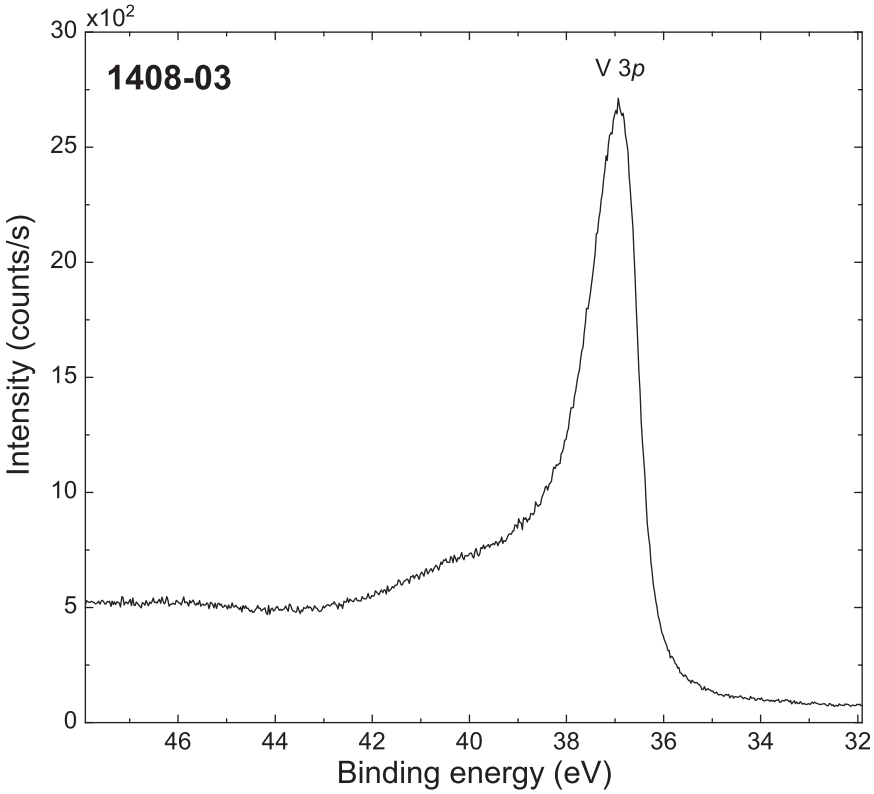
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 1746 s

Total Elapsed Time: not specified

Number of Scans: 4




- **Accession #:** 01408–03
- **Host Material:** vanadium
- **Technique:** XPS
- **Spectral Region:** V 3*p*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

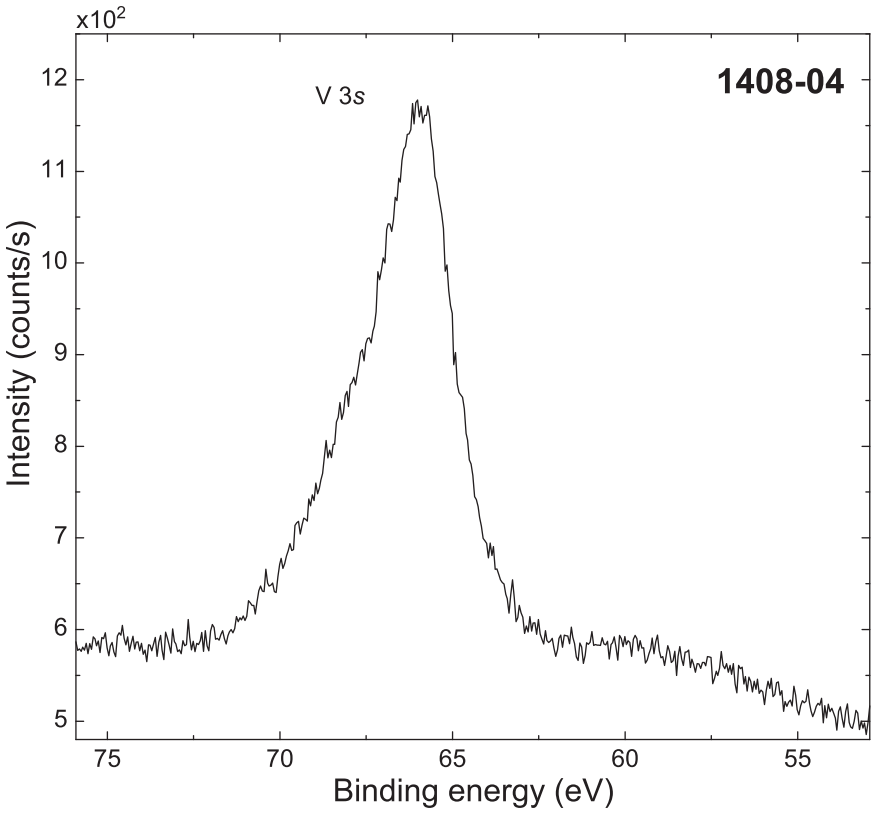
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 2692.2 s

Total Elapsed Time: not specified

Number of Scans: 14




- **Accession #:** 01408–04
- **Host Material:** vanadium
- **Technique:** XPS
- **Spectral Region:** V 3*s*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

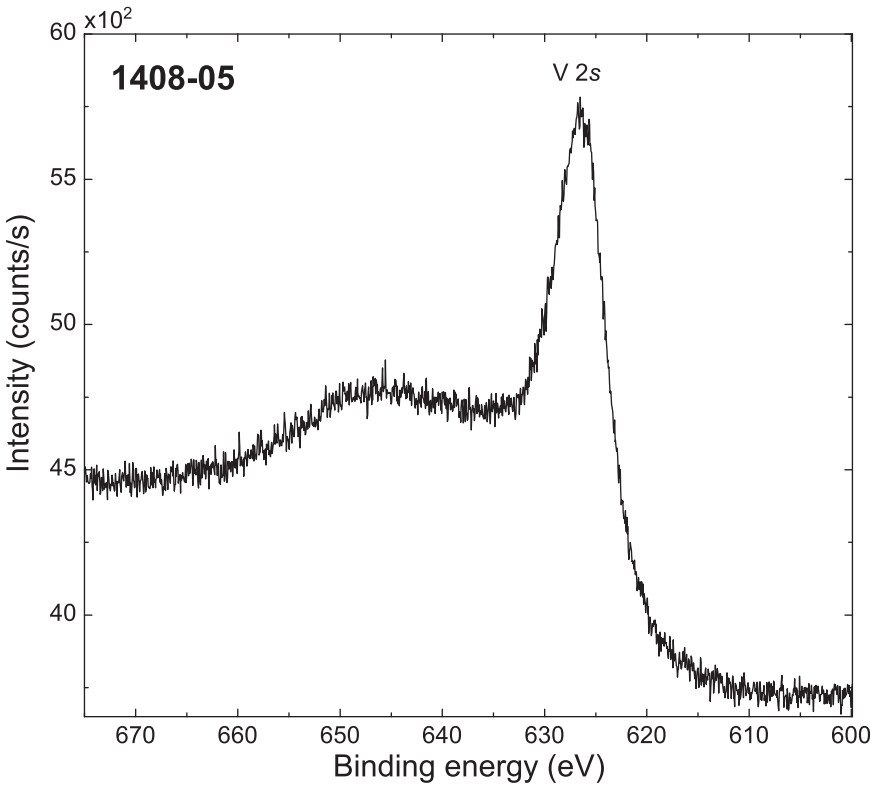
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 2766 s

Total Elapsed Time: not specified

Number of Scans: 20




- **Accession #:** 01408–05
- **Host Material:** vanadium
- **Technique:** XPS
- **Spectral Region:** V 2*s*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

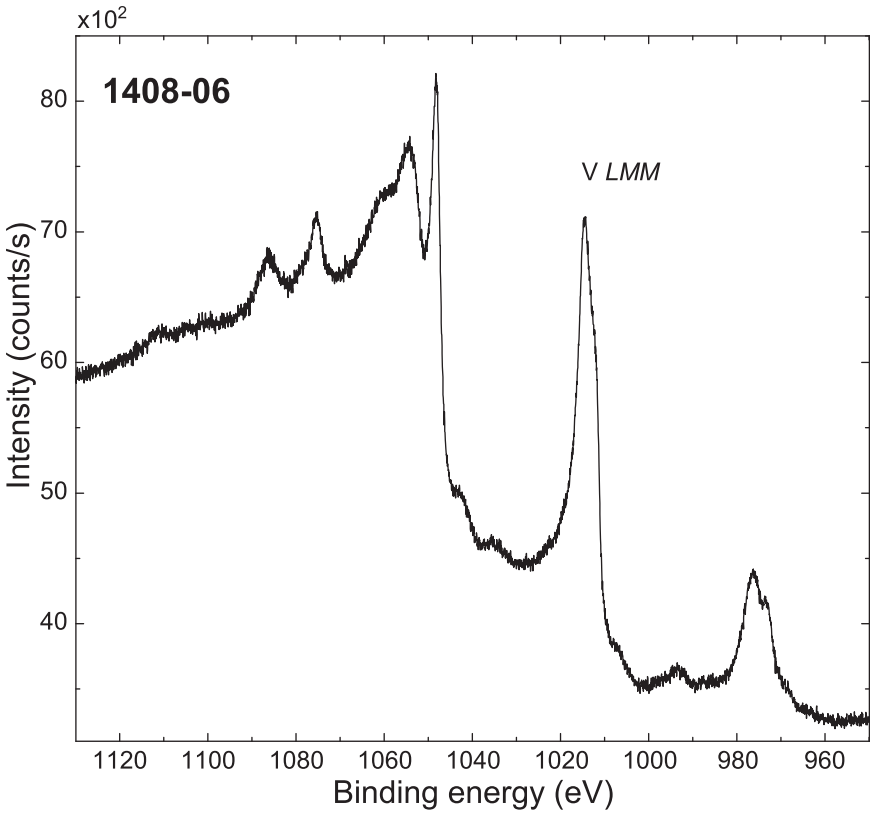
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 6404 s

Total Elapsed Time: not specified

Number of Scans: 20




- **Accession #:** 01408–06
- **Host Material:** vanadium
- **Technique:** XPS
- **Spectral Region:** V *LMM*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

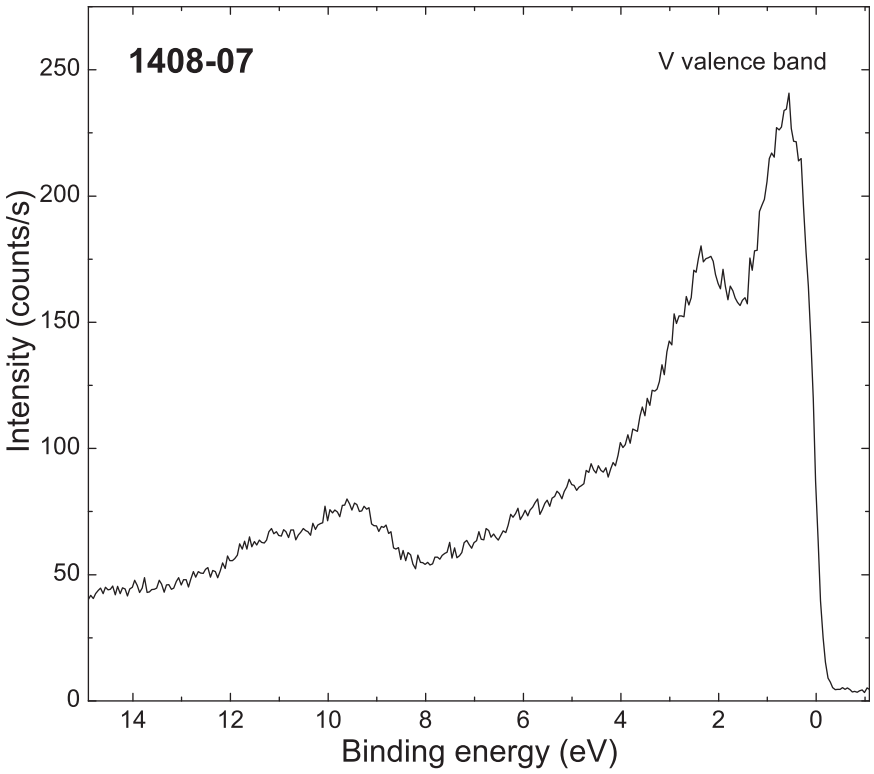
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 14404 s

Total Elapsed Time: not specified

Number of Scans: 20




- **Accession #:** 01408–07
- **Host Material:** vanadium
- **Technique:** XPS
- **Spectral Region:** V valence band

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

Analyzer Pass Energy: 10 eV

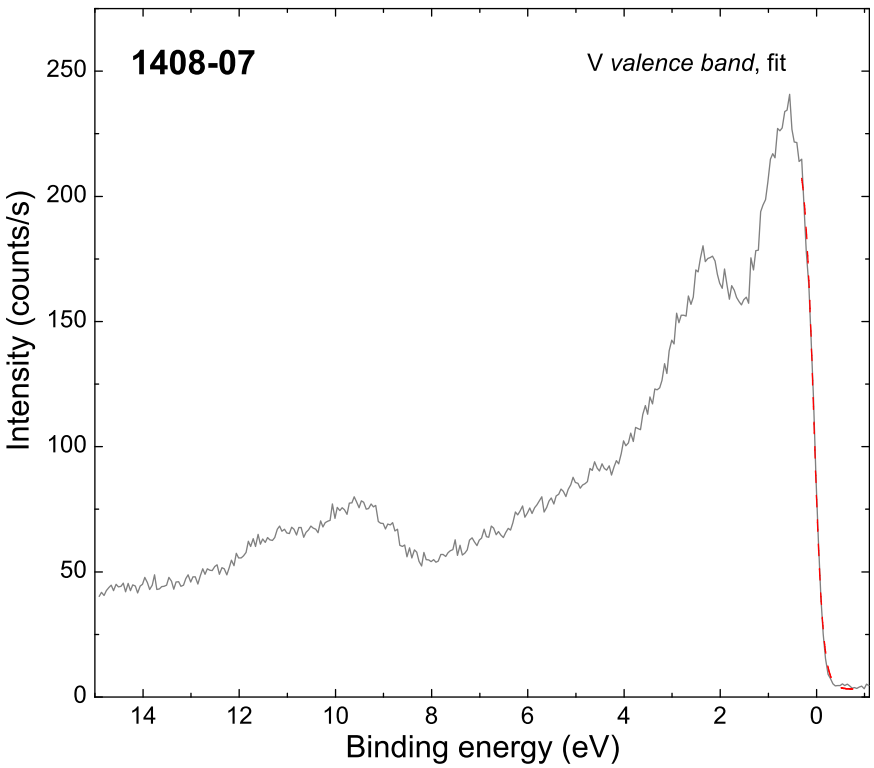
Analyzer Resolution: 0.53 eV

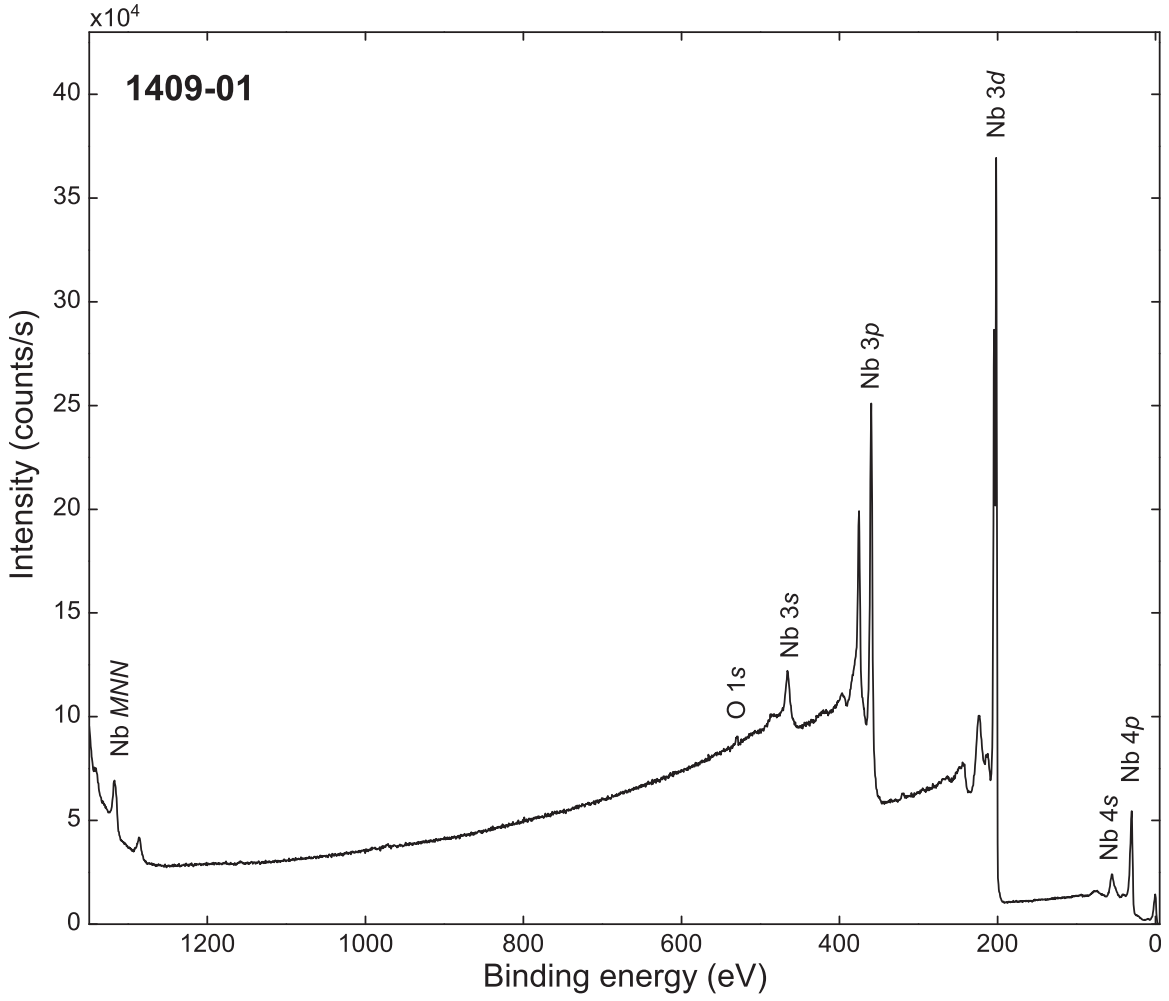
Total Signal Accumulation Time: 4815 s

Total Elapsed Time: not specified

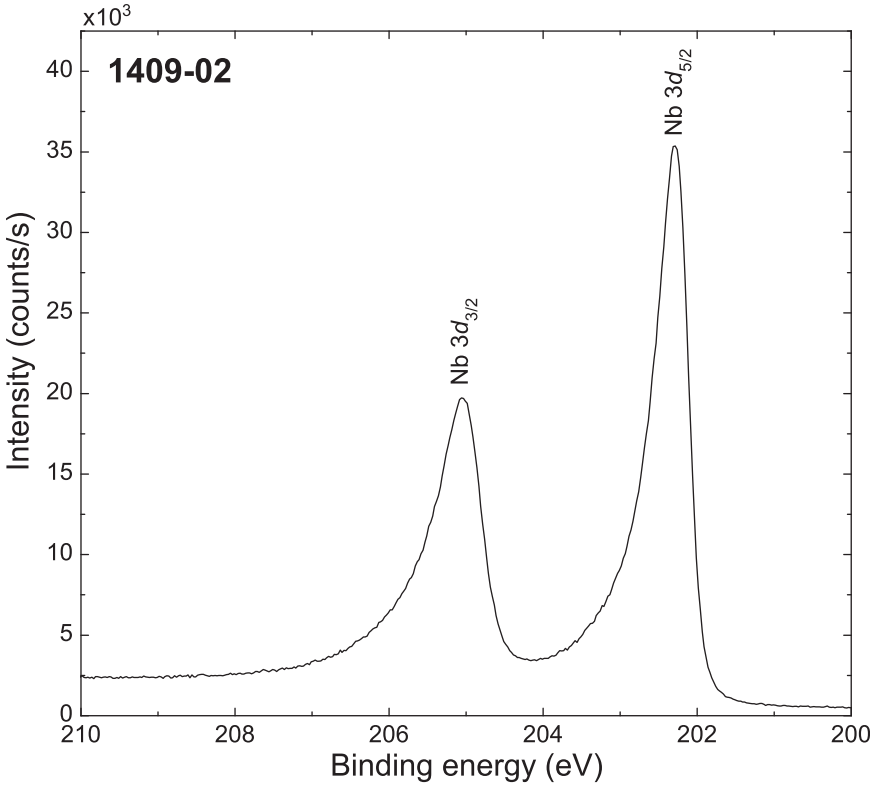
Number of Scans: 50

Comment: Following figure shows Fermi function fit calibration reference. See Analyzer Calibration Table entry for V Fermi edge.






| Accession # | 01409–01 |
|---|---|
| **Host Material** | niobium |
| **Technique** | XPS |
| **Spectral Region** | survey |
| **Instrument** | Kratos Analytical Axis Nova |
| **Excitation Source** | Al $K_\alpha$ monochromatic |
| **Source Energy** | 1486.6 eV |
| **Source Strength** | 150 W |
| **Source Size** | not specified |
| **Analyzer Type** | Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA) |
| **Incident Angle** | not specified° |
| **Emission Angle** | not specified° |
| **Analyzer Pass Energy:** | 160 eV |
| **Analyzer Resolution** | 2.0 eV |
| **Total Signal Accumulation Time** | 542 s |
| **Total Elapsed Time** | not specified |
| **Number of Scans** | 2 |




- **Accession #:** 01409–02
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb $3d_{3/2}$; Nb $3d_{5/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

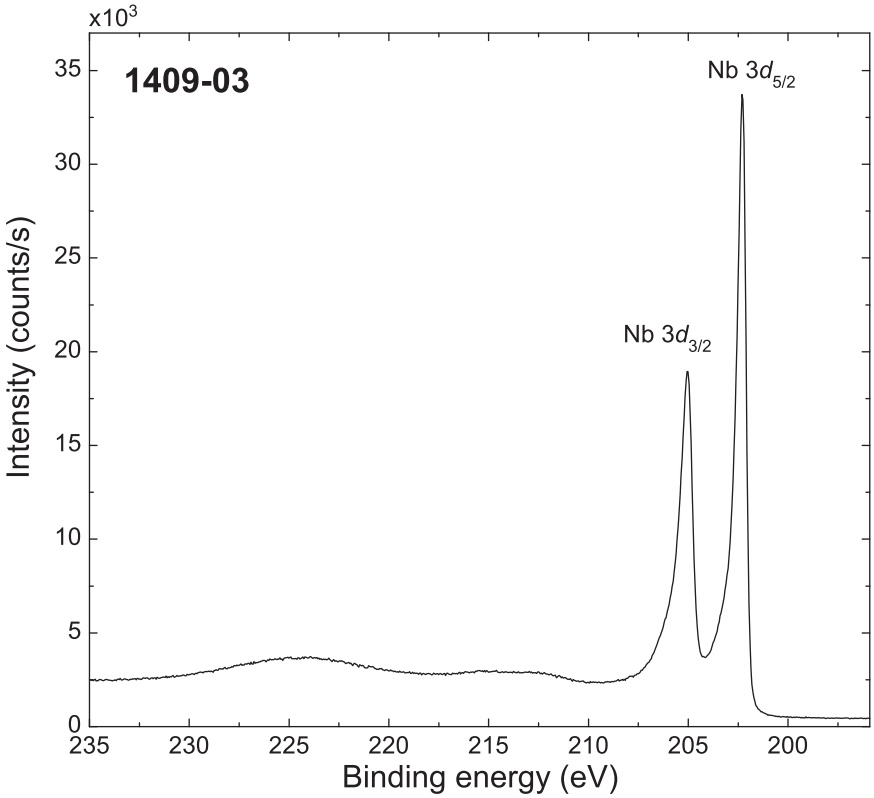
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 587 s

Total Elapsed Time: not specified

Number of Scans: 2




- **Accession #:** 01409–03
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb $3d_{5/2}$; Nb $3d_{3/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

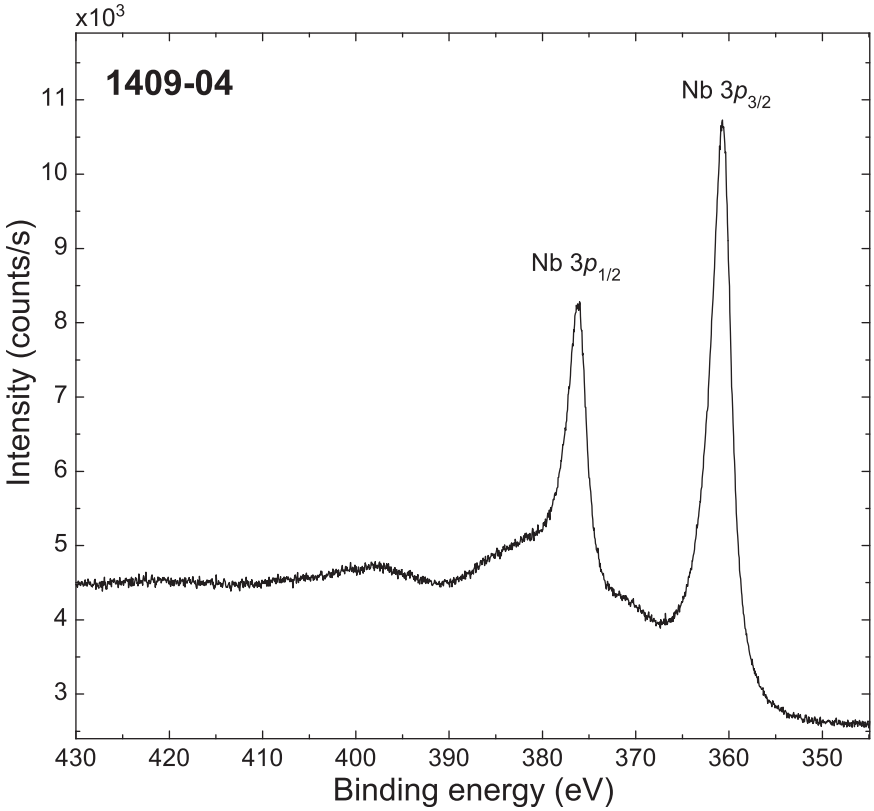
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 1467 s

Total Elapsed Time: not specified

Number of Scans: 4




- **Accession #:** 01409–04
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb $3p_{1/2}$; Nb $3p_{3/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

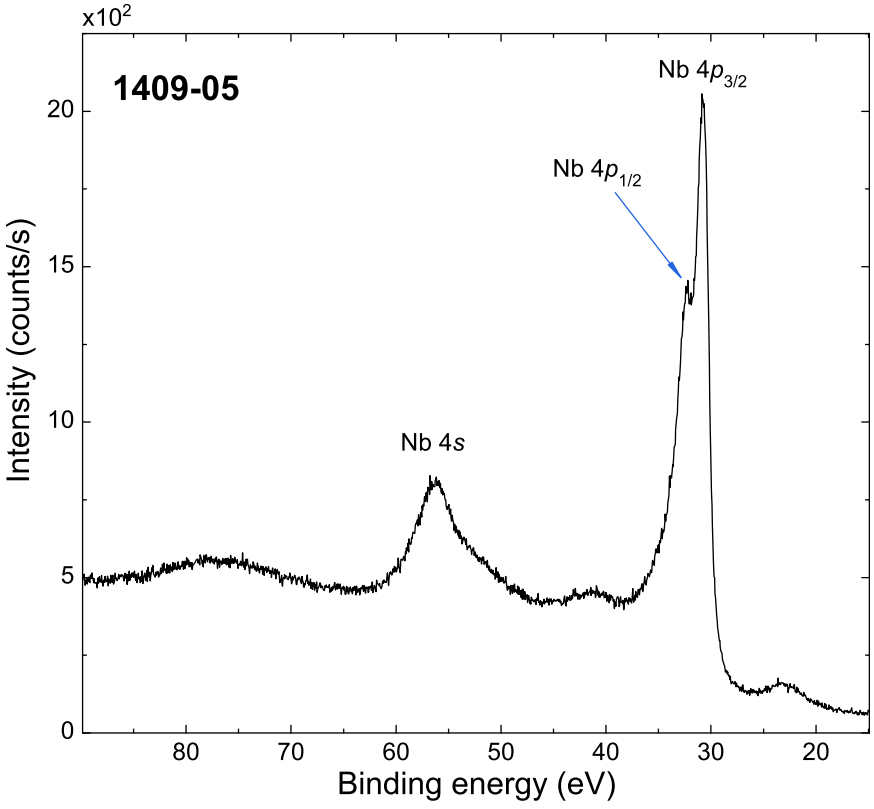
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 4690 s

Total Elapsed Time: not specified

Number of Scans: 20




- **Accession #:** 01409–05
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb 4*s*; Nb $4p_{1/2}$; Nb $4p_{3/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

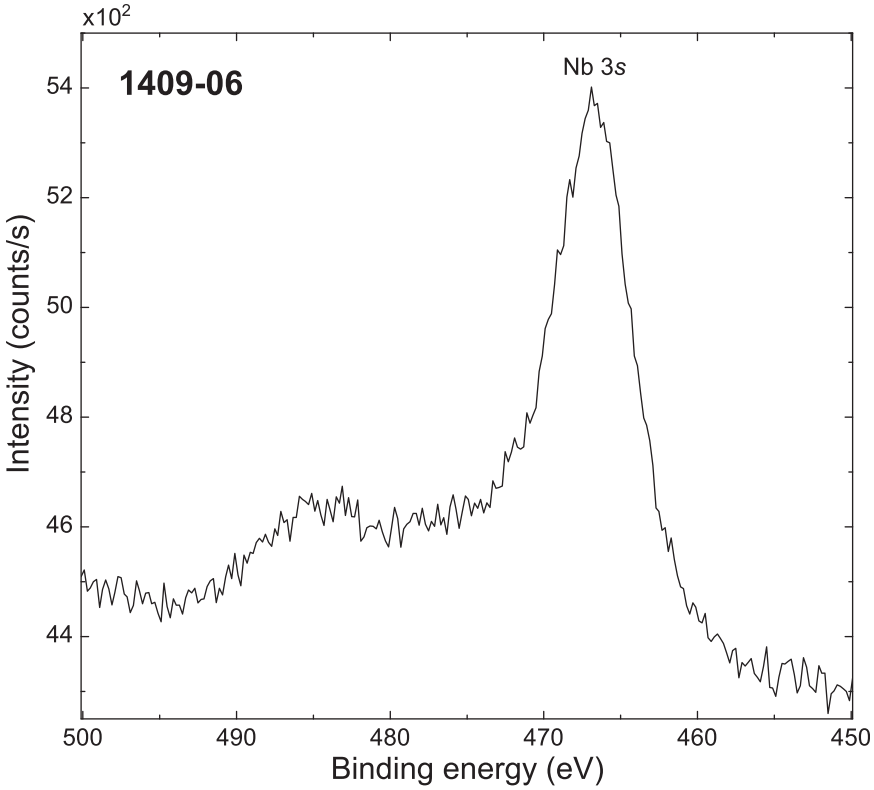
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 6004 s

Total Elapsed Time: not specified

Number of Scans: 20




- **Accession #:** 01409–06
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb 3*s*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

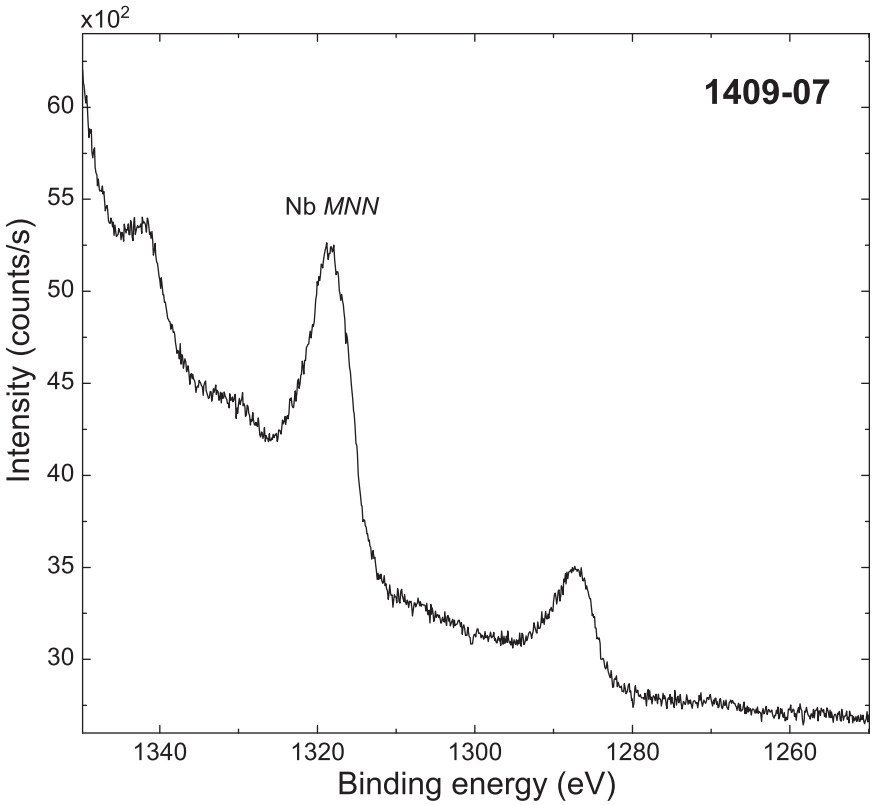
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 2408 s

Total Elapsed Time: not specified

Number of Scans: 80




- **Accession #:** 01409–07
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb *MNN*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

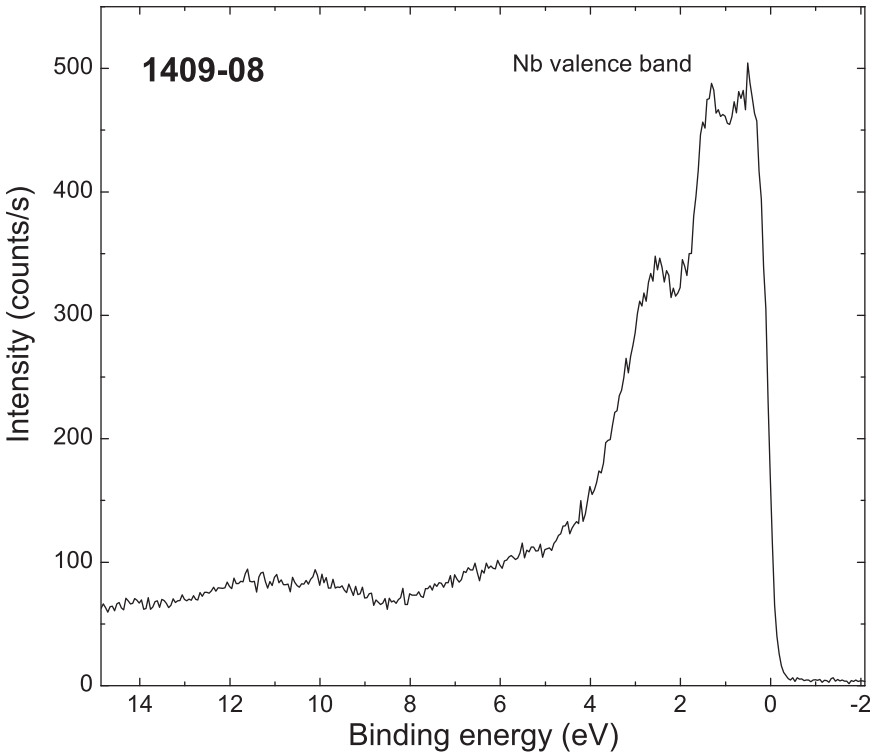
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 4004 s

Total Elapsed Time: not specified

Number of Scans: 20




- **Accession #:** 01409–08
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb valence band

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

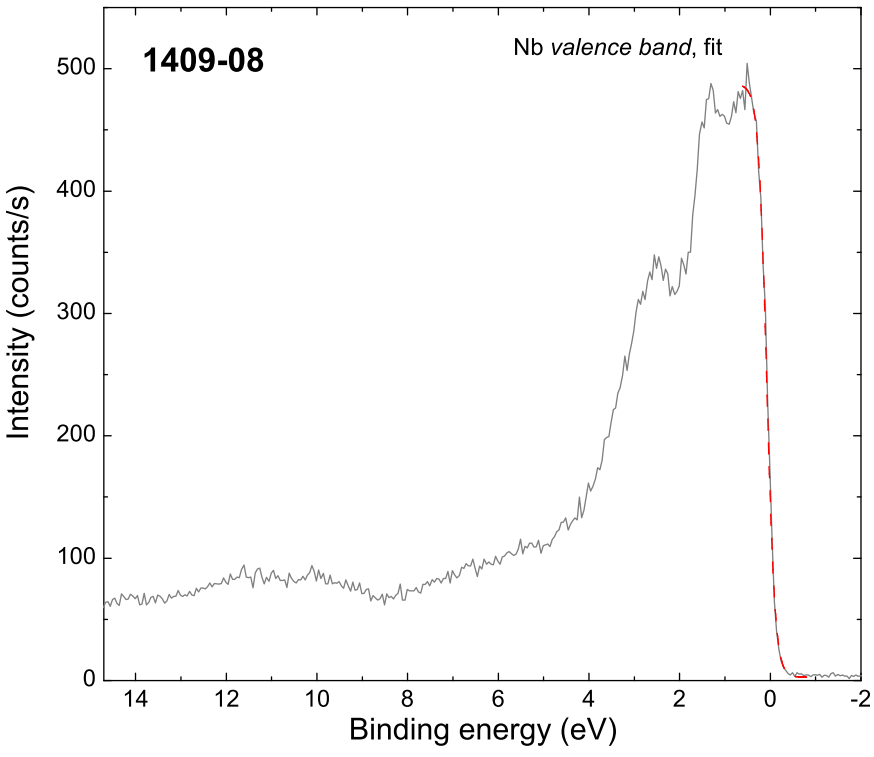
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 2046 s

Total Elapsed Time: not specified

Number of Scans: 30




- **Accession #:** 01409–08
- **Host Material:** niobium
- **Technique:** XPS
- **Spectral Region:** Nb valence band

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

Analyzer Pass Energy: 10 eV

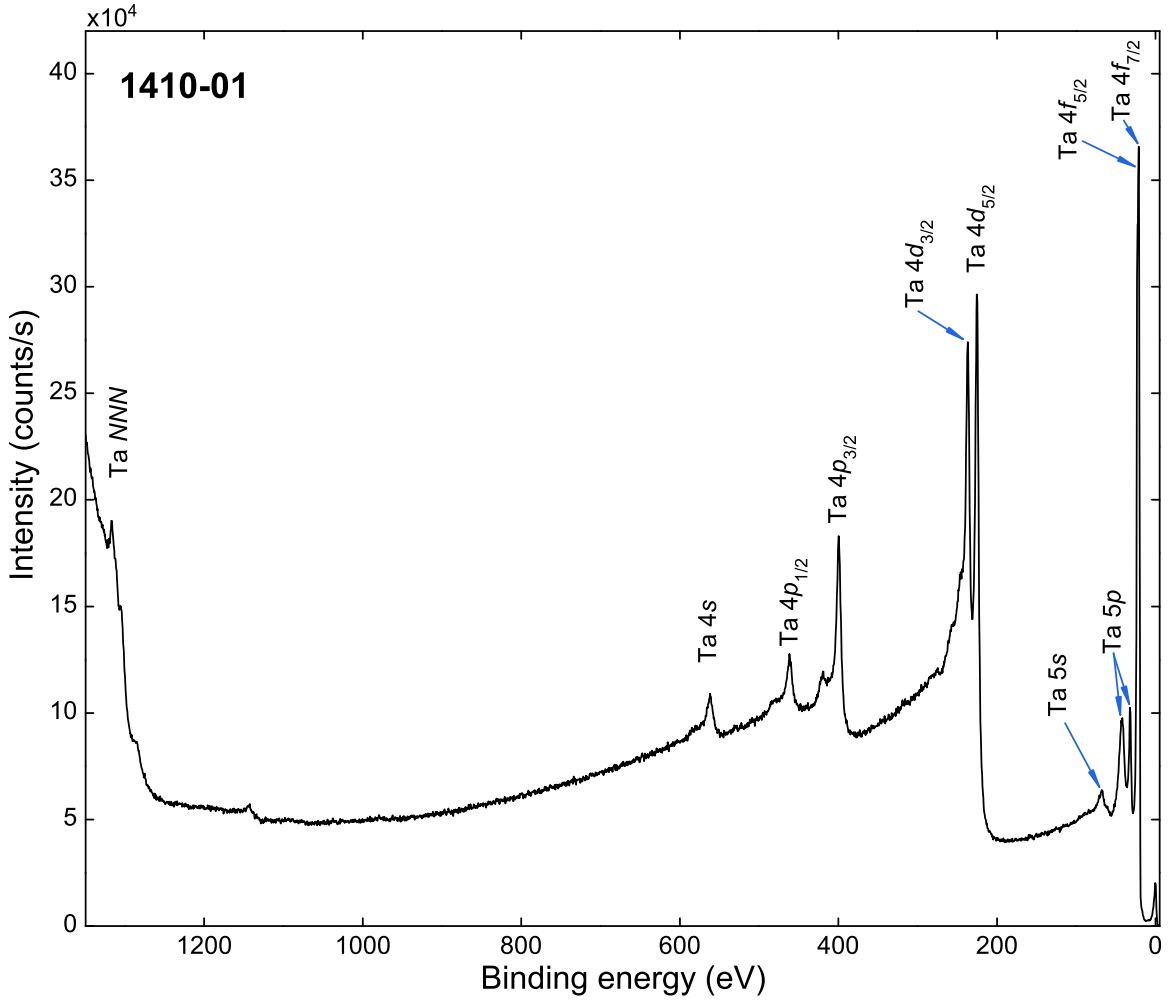
Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 2046 s

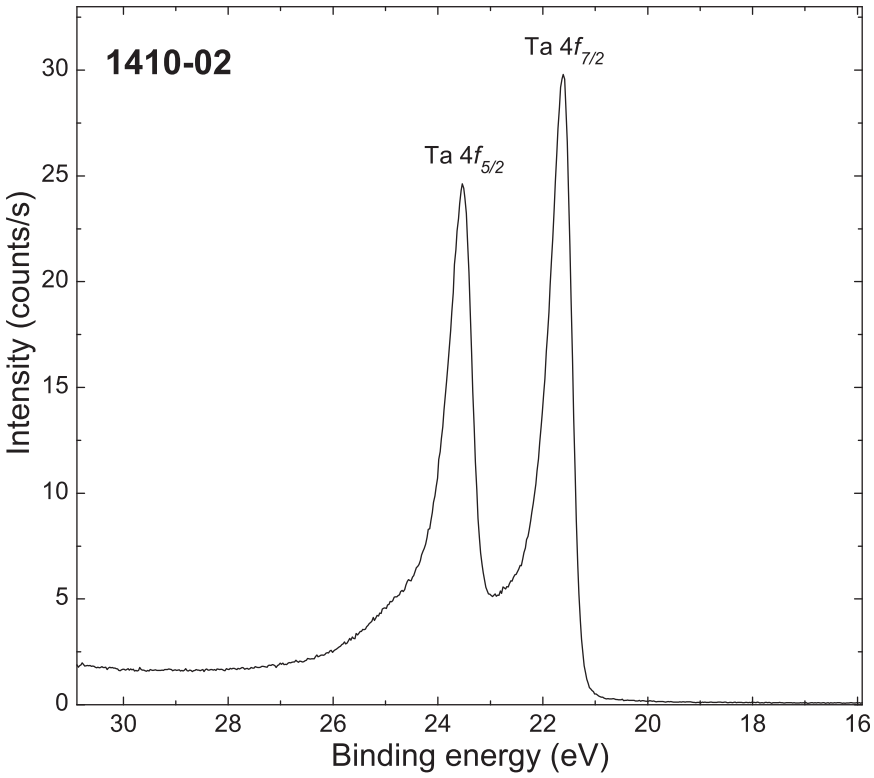
Total Elapsed Time: not specified

Number of Scans: 30

Comment: Following figure shows Fermi function fit calibration reference. See Analyzer Calibration Table entry for Nb Fermi edge.




| Accession # | 01410–01 |
|---|---|
| **Host Material** | tantalum |
| **Technique** | XPS |
| **Spectral Region** | survey |
| **Instrument** | Kratos Analytical Axis Nova |
| **Excitation Source** | Al $K_\alpha$ monochromatic |
| **Source Energy** | 1486.6 eV |
| **Source Strength** | 150 W |
| **Source Size** | not specified |
| **Analyzer Type** | Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA) |
| **Incident Angle** | not specified° |
| **Emission Angle** | not specified° |
| **Analyzer Pass Energy:** | 160 eV |
| **Analyzer Resolution** | 2.0 eV |
| **Total Signal Accumulation Time** | 271 s |
| **Total Elapsed Time** | not specified |
| **Number of Scans** | 1 |




- **Accession #:** 01410–02
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** Ta $4f_{5/2}$; Ta $4f_{7/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

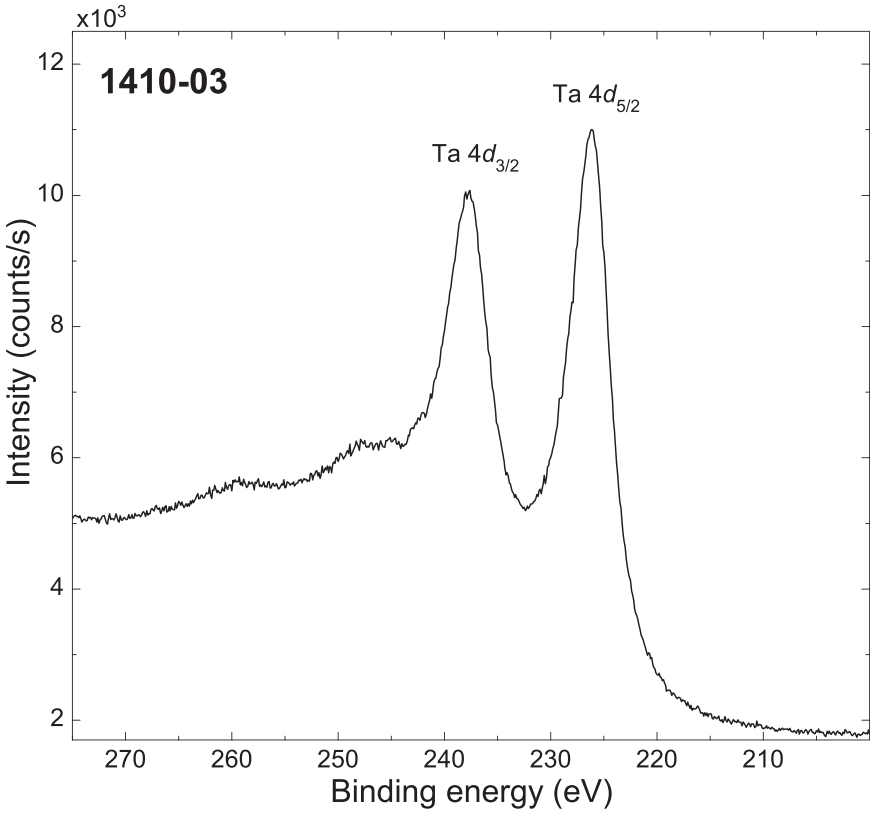
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 551 s

Total Elapsed Time: not specified

Number of Scans: 2




- **Accession #:** 01410–03
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** Ta $4d_{3/2}$; Ta $4d_{5/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

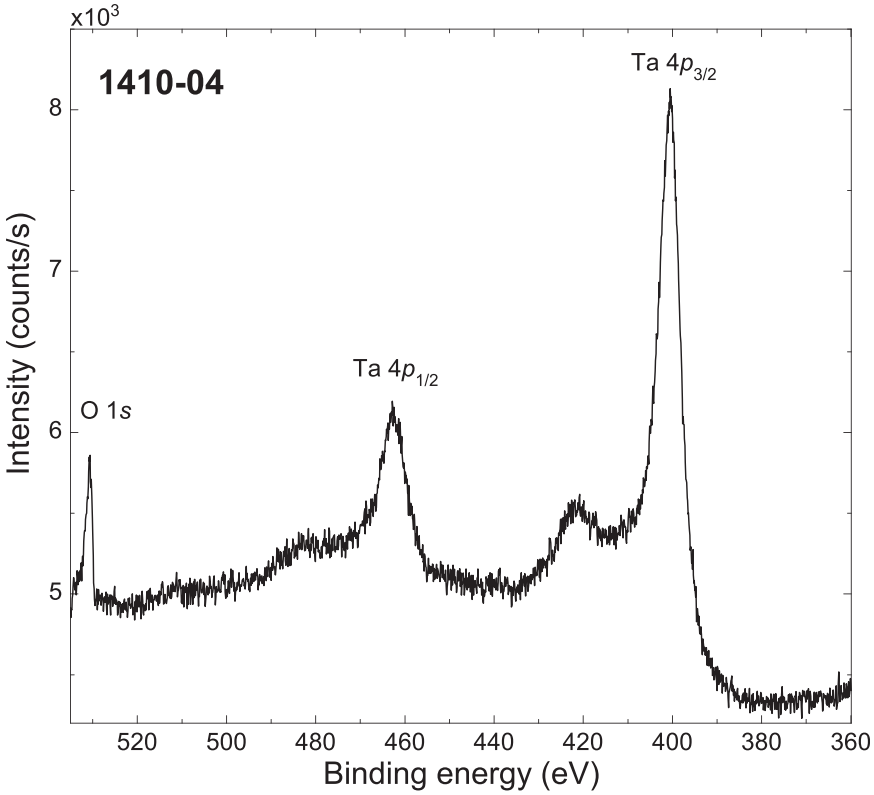
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 2635 s

Total Elapsed Time: not specified

Number of Scans: 16




- **Accession #:** 01410–04
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** O 1*s*; Ta 4$p_{1/2}$; Ta 4$p_{3/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

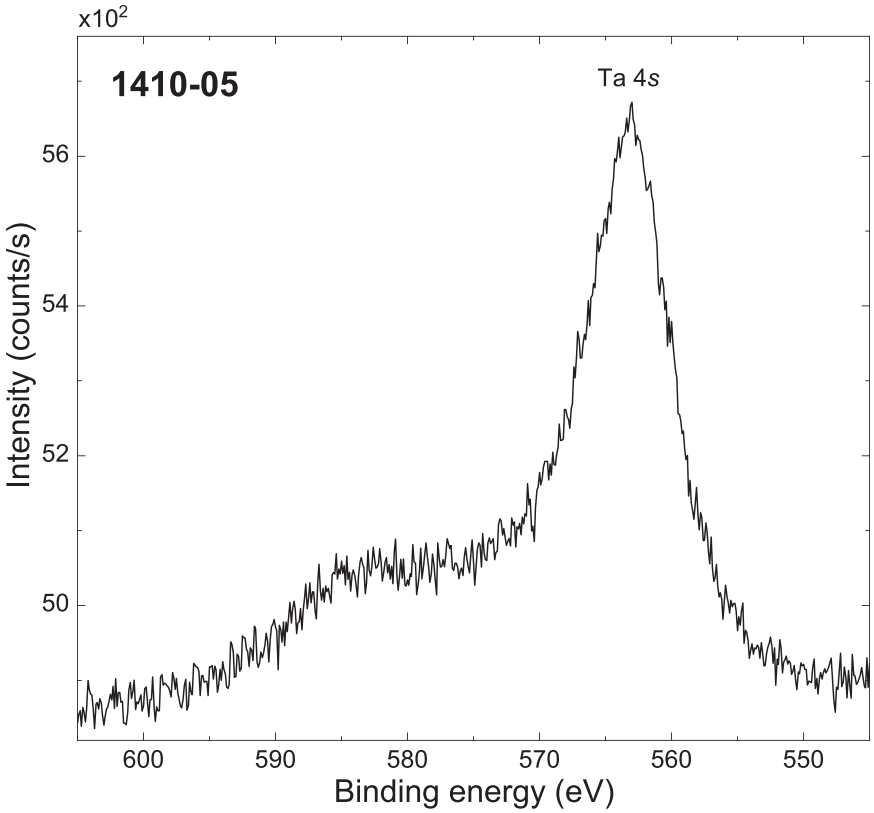
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 3226 s

Total Elapsed Time: not specified

Number of Scans: 26




- **Accession #:** 01410–05
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** Ta 4*s*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

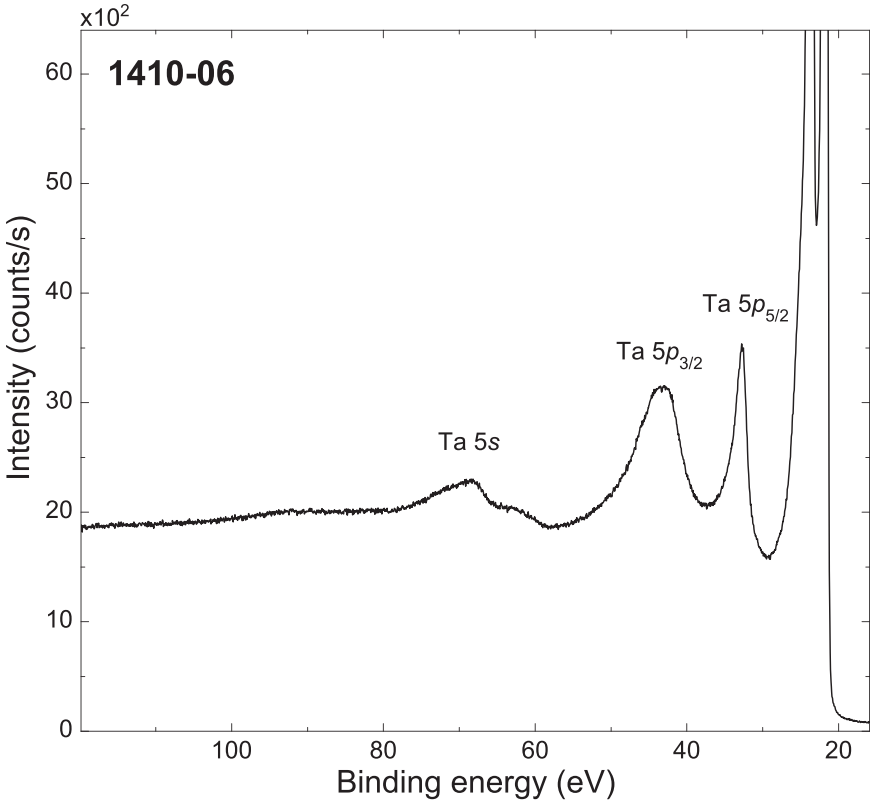
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 10217 s

Total Elapsed Time: not specified

Number of Scans: 64




- **Accession #:** 01410–06
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** Ta 5*s*; Ta $5p_{1/2}$; Ta $5p_{3/2}$

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

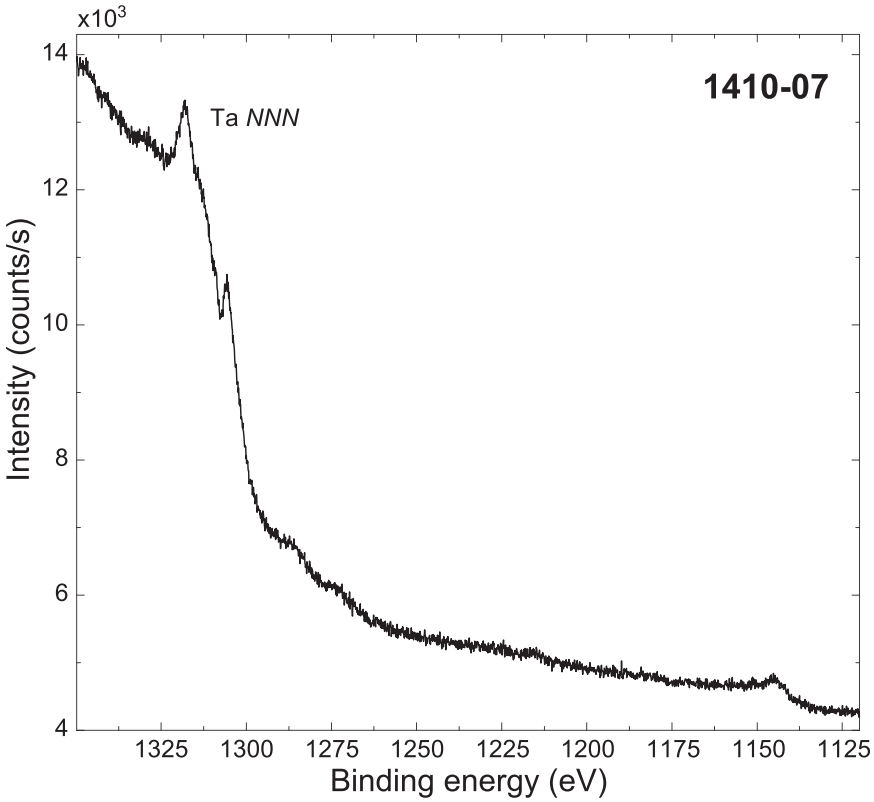
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 17156 s

Total Elapsed Time: not specified

Number of Scans: 18




- **Accession #:** 01410–07
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** Ta *NNN*

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

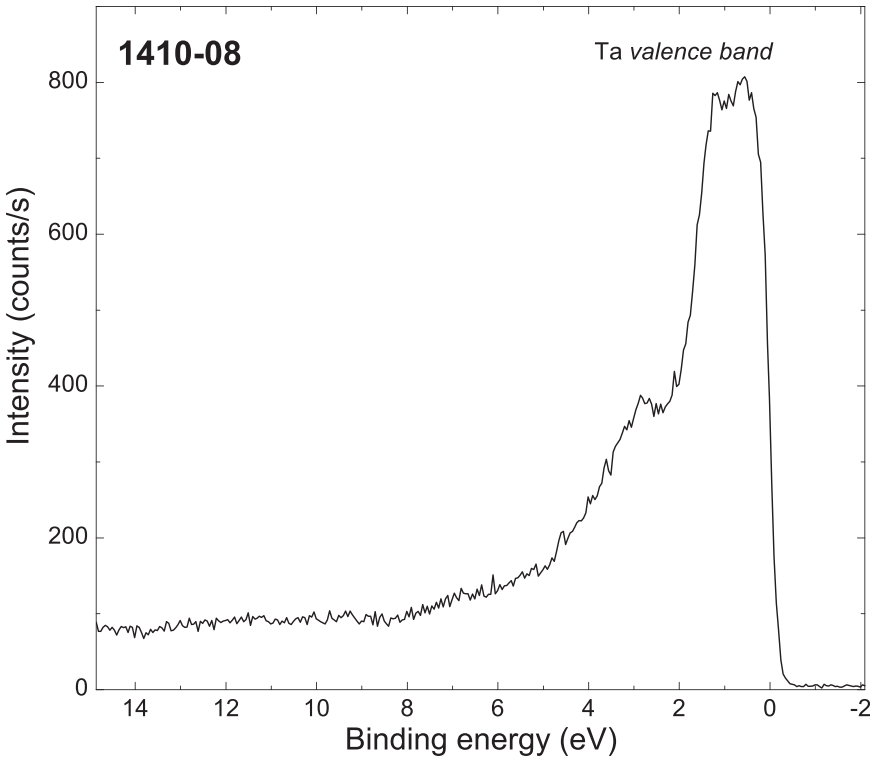
Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 4142 s

Total Elapsed Time: not specified

Number of Scans: 18




- **Accession #:** 01410–08
- **Host Material:** tantalum
- **Technique:** XPS
- **Spectral Region:** Ta valence band

Instrument: Kratos Analytical Axis Nova

Excitation Source: Al $K_\alpha$ monochromatic

Source Energy: 1486.6 eV

Source Strength: 150 W

Source Size: not specified

Analyzer Type: Combined hemispherical analyzer (HSA) and spherical mirror analyzer (SMA)

Incident Angle: not specified°

Emission Angle: not specified°

Analyzer Pass Energy: 10 eV

Analyzer Resolution: 0.53 eV

Total Signal Accumulation Time: 1364 s

Total Elapsed Time: not specified

Number of Scans: 20

Comment: Following figure shows Fermi function fit calibration reference. See Analyzer Calibration Table entry for Ta Fermi edge.